US009203835B2

(12) **United States Patent**
Jakobsson

(10) **Patent No.: US 9,203,835 B2**
(45) **Date of Patent: Dec. 1, 2015**

(54) **SYSTEMS AND METHODS FOR AUTHENTICATING A USER BASED ON A BIOMETRIC MODEL ASSOCIATED WITH THE USER**

(71) Applicant: **EBAY INC.**, San Jose, CA (US)

(72) Inventor: **Bjorn Markus Jakobsson**, Portola Valley, CA (US)

(73) Assignee: **Paypal, Inc.**, San Jose, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 66 days.

(21) Appl. No.: **14/033,851**

(22) Filed: **Sep. 23, 2013**

(65) **Prior Publication Data**

US 2014/0250515 A1 Sep. 4, 2014

Related U.S. Application Data

(60) Provisional application No. 61/771,785, filed on Mar. 1, 2013.

(51) **Int. Cl.**

H04L 29/06	(2006.01)
H04L 9/32	(2006.01)
G06F 21/32	(2013.01)

(52) **U.S. Cl.**

CPC ***H04L 63/0861*** (2013.01); ***G06F 21/32*** (2013.01); ***H04L 9/3231*** (2013.01)

(58) **Field of Classification Search**

CPC G06F 21/30; G06F 21/00; G06F 21/32; H04L 9/32; H04L 9/3231; H04L 63/0861

USPC 726/7; 713/168, 182, 186

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,185,316	B1 *	2/2001	Buffam	382/115
6,317,834	B1 *	11/2001	Gennaro et al.	713/186
6,851,051	B1 *	2/2005	Bolle et al.	382/115
8,533,485	B1 *	9/2013	Bansal et al.	713/186
2001/0048025	A1 *	12/2001	Shinn	235/382
2002/0164058	A1 *	11/2002	Aggarwal et al.	382/125
2004/0215615	A1	10/2004	Larsson et al.	
2006/0294390	A1 *	12/2006	Navratil et al.	713/182
2011/0082791	A1 *	4/2011	Baghdasaryan et al.	705/44
2013/0108145	A1 *	5/2013	Cobb et al.	382/141
2013/0265218	A1 *	10/2013	Moscarillo	345/156

OTHER PUBLICATIONS

International Search Report for PCT/US2014/018310 dated Jul. 14, 2014, 2 pages.

Napa SAE-BAE et. al., Biometric-Rich Gestures: A Novel Approach to Authentication on Multi-touch Devices, CHI 2012, May 5-10, 2012 Austin, Texas, pp. 977-986.

* cited by examiner

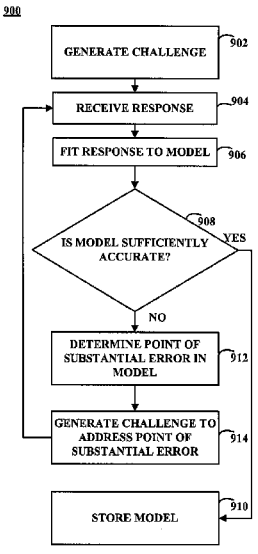
Primary Examiner — Matthew Smithers

(74) *Attorney, Agent, or Firm* — Haynes and Boone, LLP

(57) **ABSTRACT**

Systems and methods as provided herein may create a biometric model associated with a user. The created biometric model may be used to generate challenges that are presented to the user for authentication purposes. A user response to the challenge may be compared to an expected response, and if the user response matches within a predetermined error of the expected response, the user may be authenticated. The systems and methods may further generate challenges that are adaptively designed to address weaknesses or errors in the created model such that the model is more closely associated with a user and the user is more likely to be the only person capable of successfully responding to the generated challenges.

19 Claims, 9 Drawing Sheets



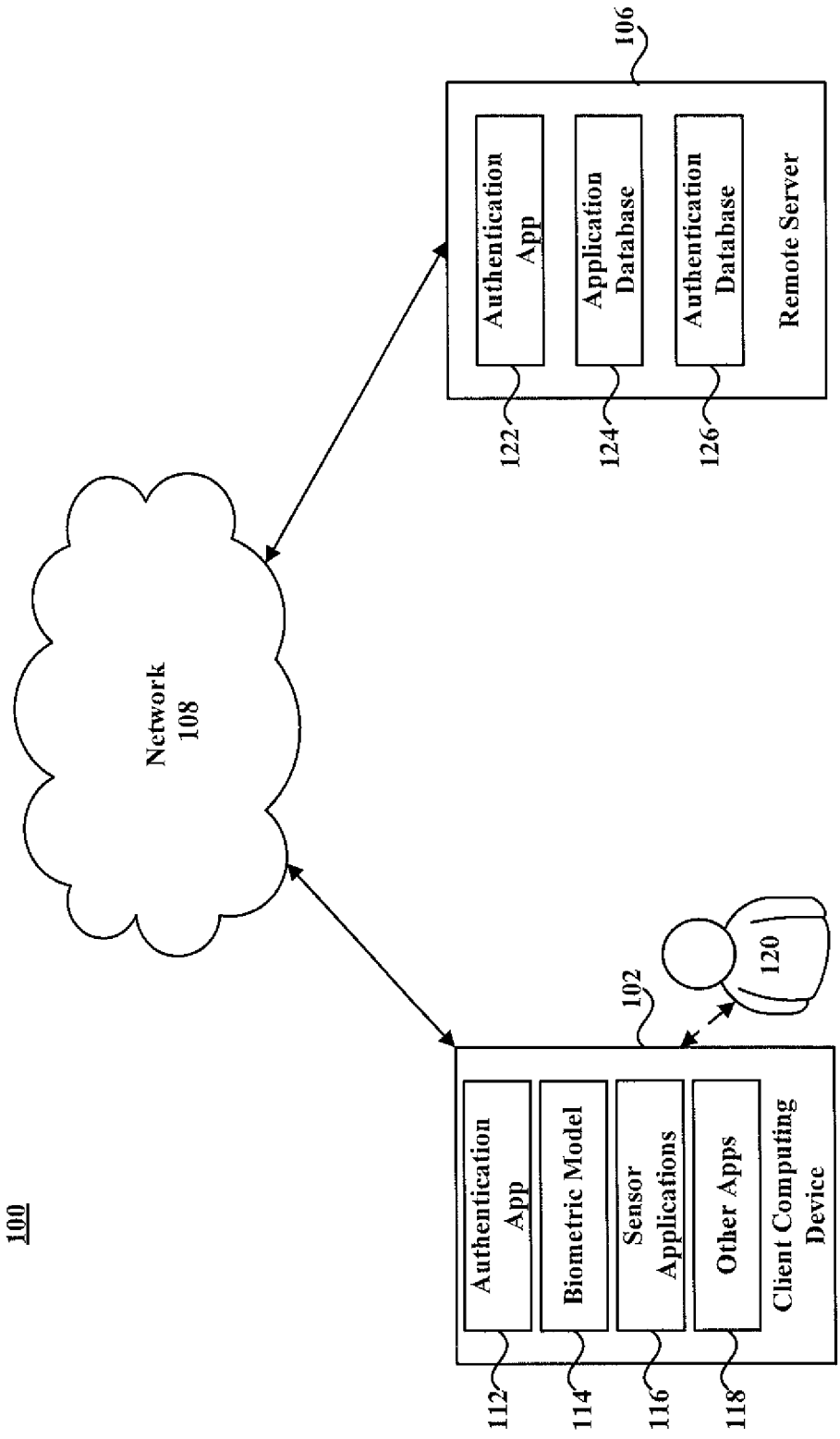

100
Network
108
106
Remote Server
Authentication App
Application Database
Authentication Database
122
124
126
102
120
Client Computing Device
Authentication App
Biometric Model
Sensor Applications
Other Apps
112
114
116
118

FIG. 1

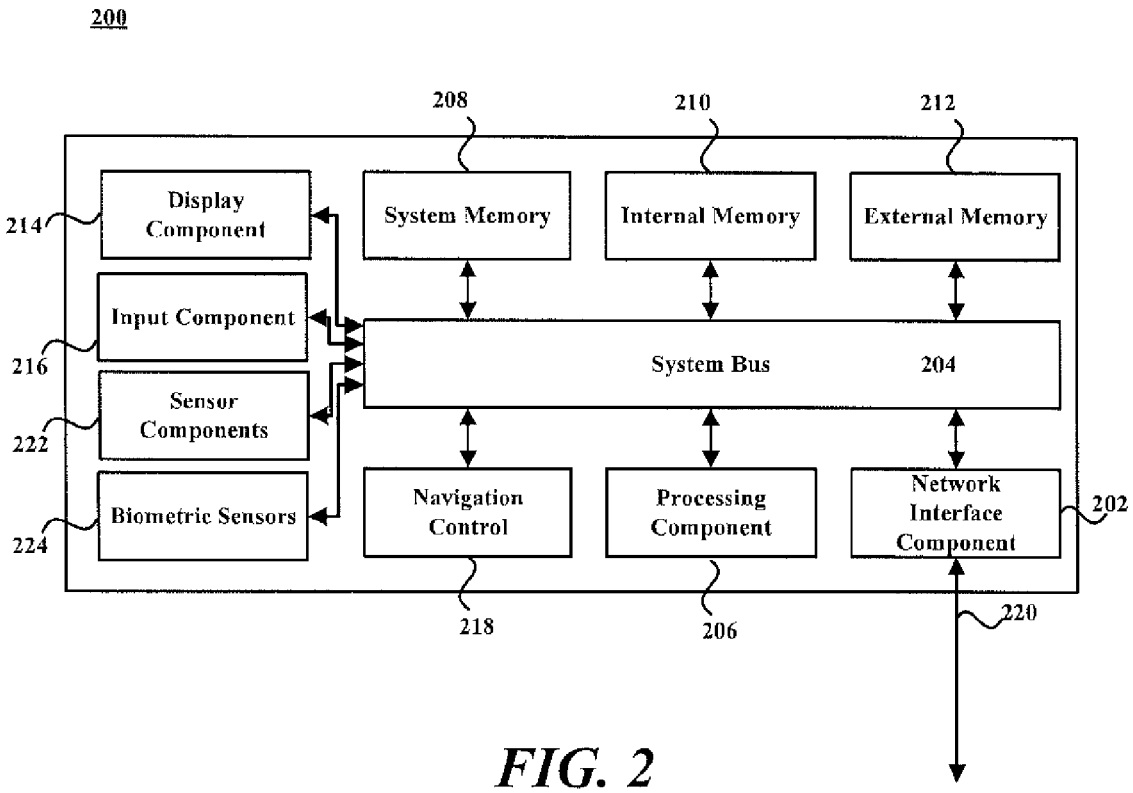

200
208
210
212
Display Component
214
System Memory
Internal Memory
External Memory
Input Component
216
System Bus
204
Sensor Components
222
Biometric Sensors
224
Navigation Control
Processing Component
Network Interface Component
202
218
206
220

FIG. 2

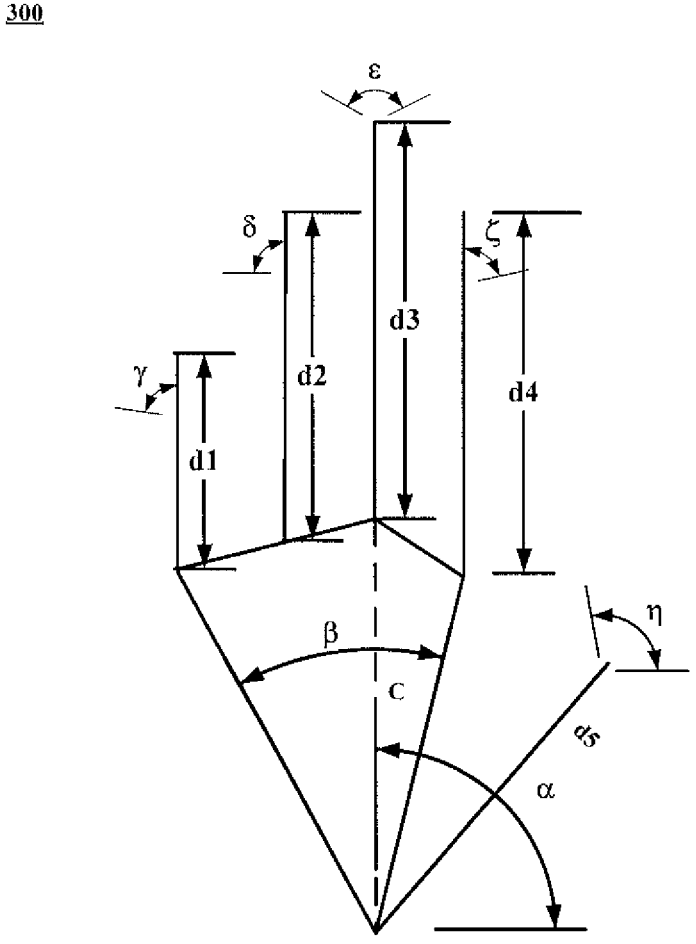


FIG. 3

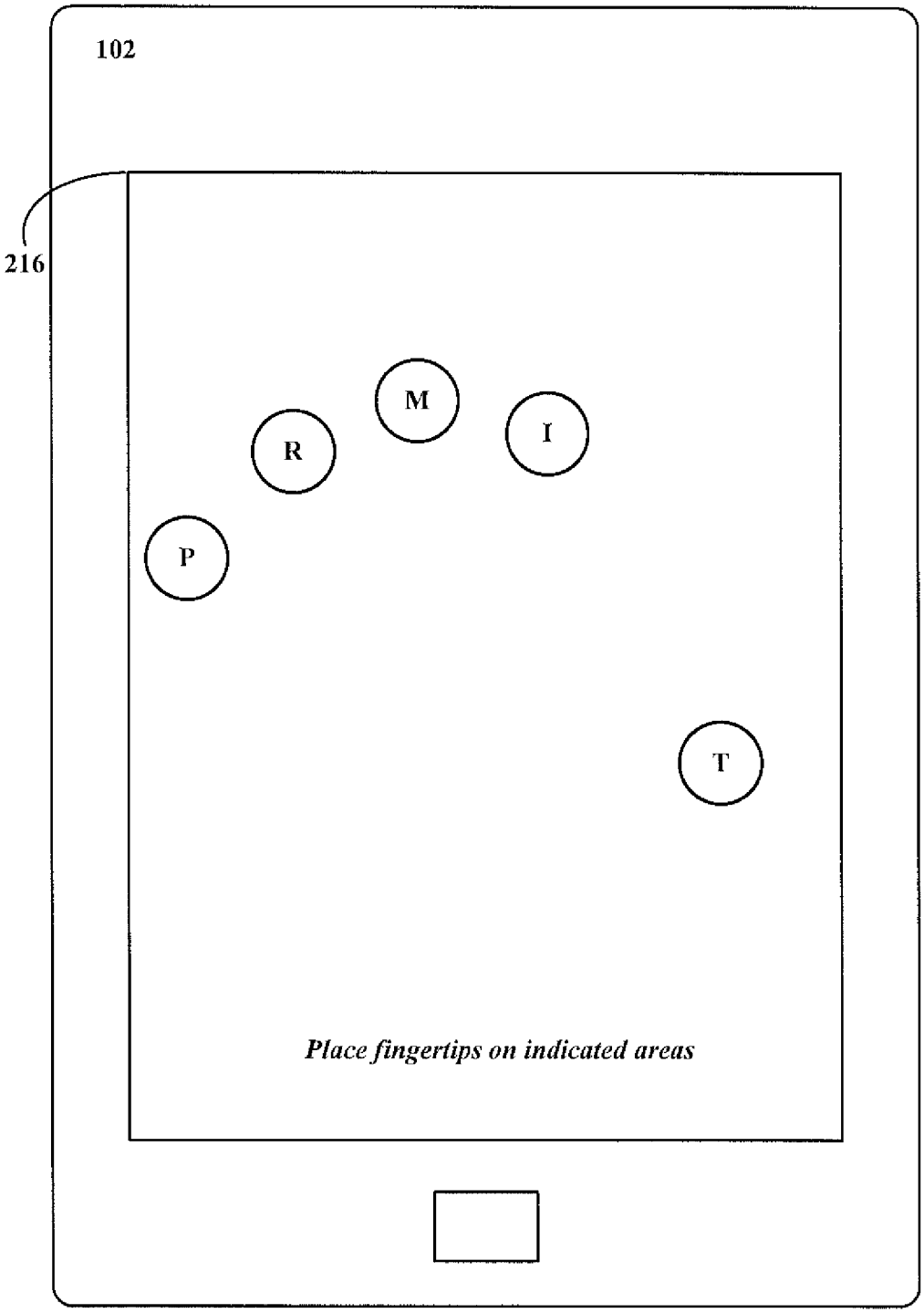


FIG. 4

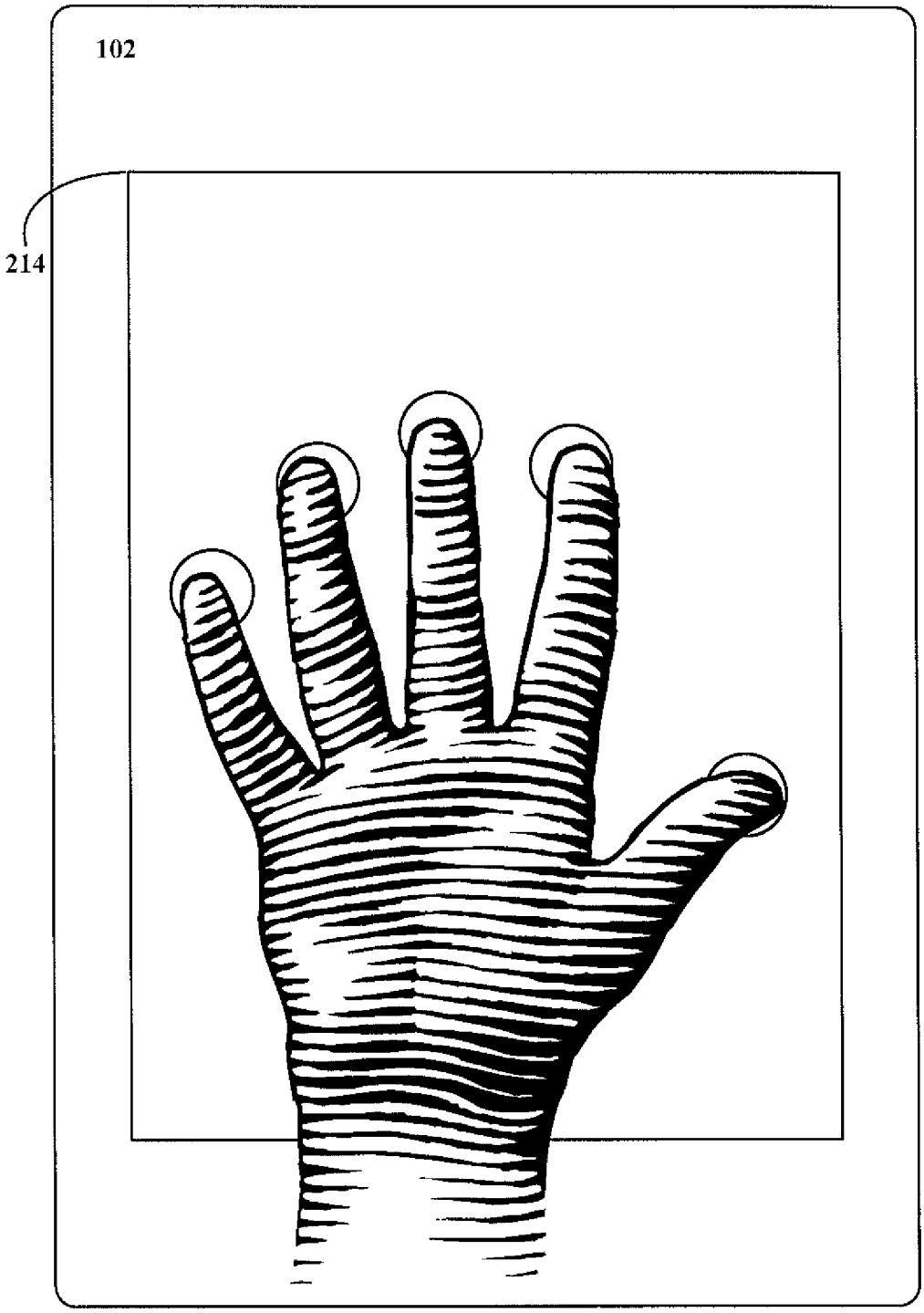


FIG. 5

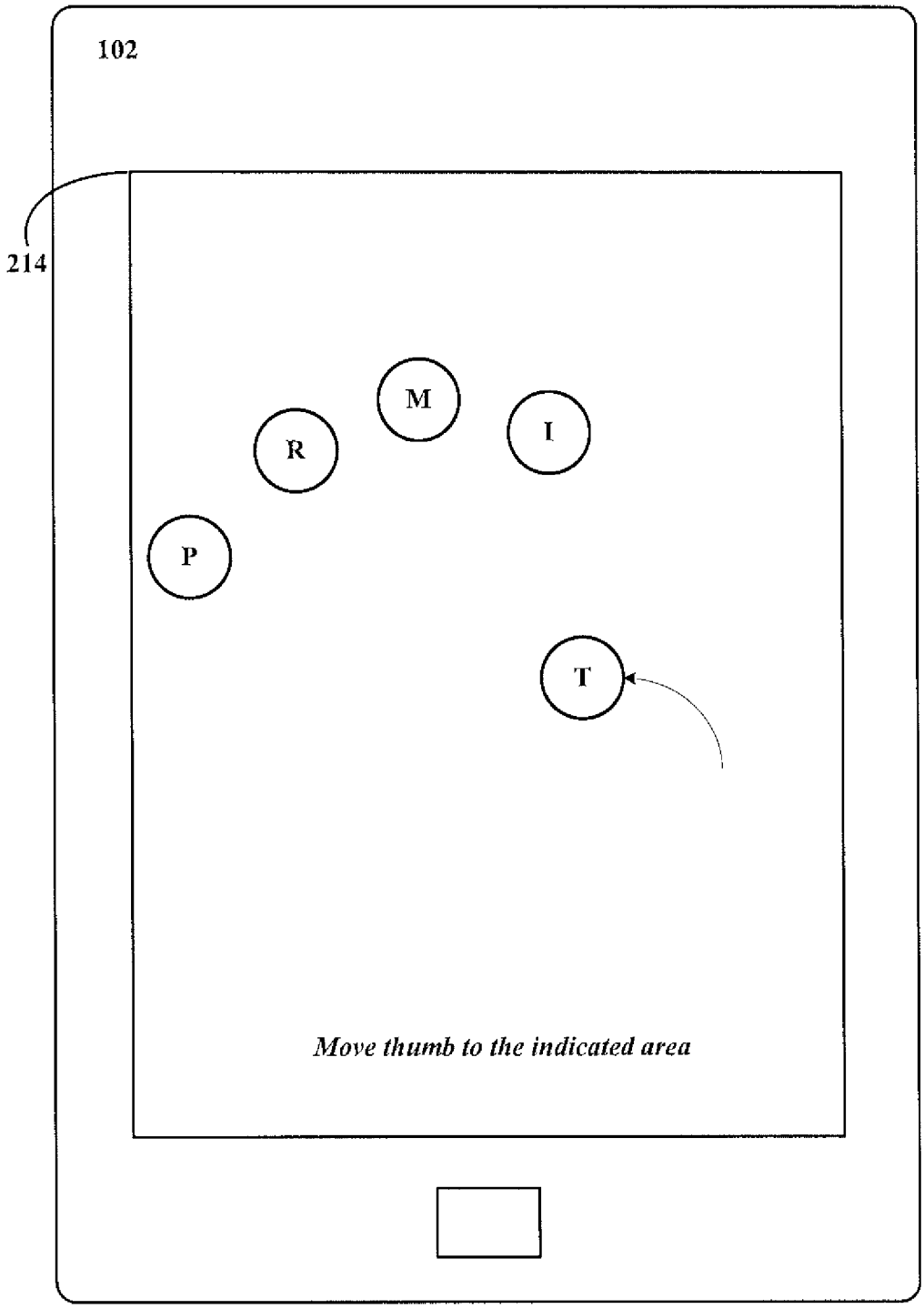


FIG. 6

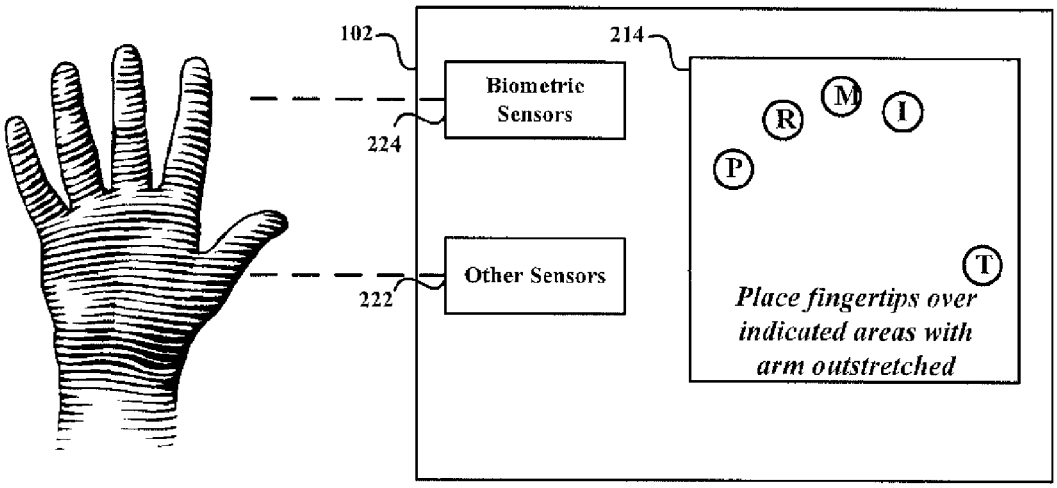

102
214
Biometric Sensors
224
Other Sensors
222
M
R
I
P
T
Place fingertips over indicated areas with arm outstretched

FIG. 7

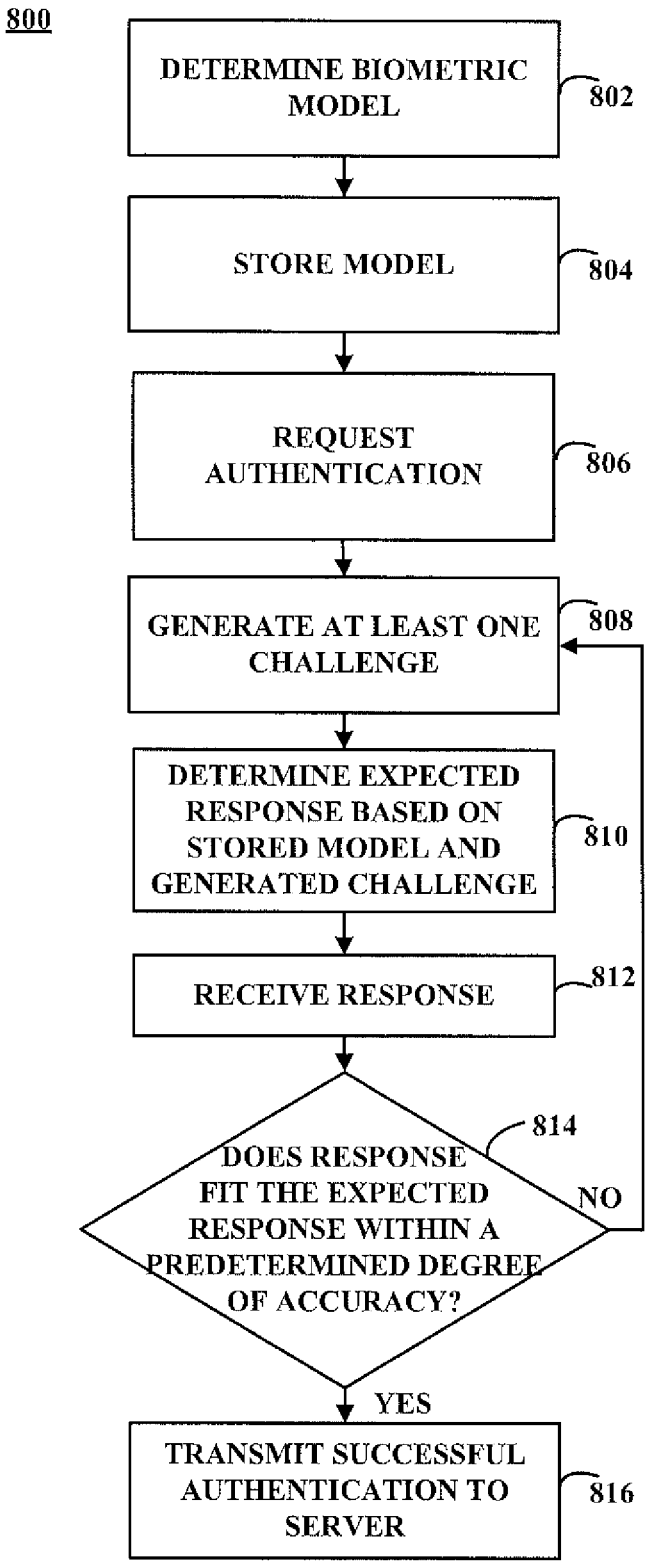

800
DETERMINE BIOMETRIC MODEL
802
STORE MODEL
804
REQUEST AUTHENTICATION
806
GENERATE AT LEAST ONE CHALLENGE
808
DETERMINE EXPECTED RESPONSE BASED ON STORED MODEL AND GENERATED CHALLENGE
810
RECEIVE RESPONSE
812
DOES RESPONSE FIT THE EXPECTED RESPONSE WITHIN A PREDETERMINED DEGREE OF ACCURACY?
814
NO
YES
TRANSMIT SUCCESSFUL AUTHENTICATION TO SERVER
816

FIG. 8

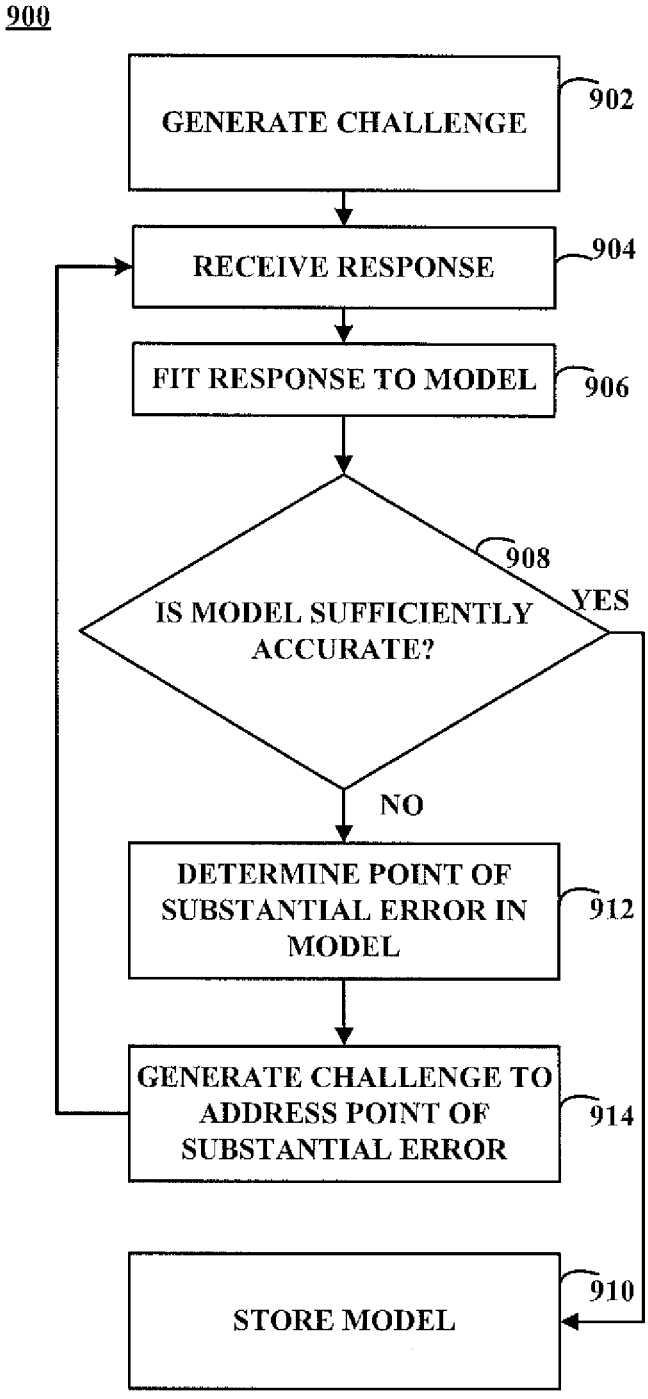

900
GENERATE CHALLENGE
902
RECEIVE RESPONSE
904
FIT RESPONSE TO MODEL
906
IS MODEL SUFFICIENTLY ACCURATE?
908
YES
NO
DETERMINE POINT OF SUBSTANTIAL ERROR IN MODEL
912
GENERATE CHALLENGE TO ADDRESS POINT OF SUBSTANTIAL ERROR
914
STORE MODEL
910

FIG. 9

SYSTEMS AND METHODS FOR AUTHENTICATING A USER BASED ON A BIOMETRIC MODEL ASSOCIATED WITH THE USER

CROSS REFERENCE TO RELATED APPLICATIONS

Pursuant to 35 U.S.C. §119(e), this application claims priority to the filing date of U.S. Provisional Patent Application No. 61/771,785, filed on Mar. 1, 2013, the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

1. Technical Field

Embodiments disclosed herein are related to systems and methods for authenticating a user based on a biometric model associated with the user. In particular, systems and methods disclosed herein may create a biometric model associated with a user, and use the created model to authenticate a user.

2. Related Art

Known biometric authentication techniques include fingerprint sensors and hand signature sensors. Fingerprint sensors are included with some personal computing devices and require a user to place or swipe a finger on the sensor. The data obtained by the sensor is compared to a stored or external template or model to determine user identity based on a probability that certain indicia within the template are met. Hand signature authentication techniques require a user to sign on an electronic pad. Indicia about the received signature, including a speed, pressure, and the actual pattern represented by the signature are analyzed to determine a probability of the indicia matching. Iris and other optical authentication is similar, where an optical scan is taken, and certain indicia are matched to a template. These techniques are all risk-based authentication techniques where a determination is made as to whether certain features are met based on a predetermined threshold.

Biometric authentication methods based on indicia of a user's hand have been recently discloses. The disclosed methods require the user to perform an action with the hand many times that is recorded by a biometric sensor. Then, to authenticate, the user is again asked to perform the action. The performed action is compared to the recorded actions to determine how closely the performed action matches the recorded actions, wherein enough similarity results in a successful authentication. The idea is that due to the differences between individual user's hands, there is enough entropy that even if an attacker sees a user performing the action, it is unlikely that the attacker has the same hand and, thus, the action will be performed differently. However, this authentication method does not understand what a hand looks like, but only asks that the user memorize the action so that they can perform it when asked.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a block diagram of a networked system, consistent with some embodiments.

FIG. **2** is a diagram illustrating computing system, consistent with some embodiments,

FIG. **3** is a diagram illustrating a biometric model of a user's hand, consistent with some embodiments.

FIG. **4** is a diagram illustrating an example of a challenge that may be used to create a biometric model, consistent with some embodiments.

FIG. **5** is a diagram illustrating user performing the challenge shown in FIG. **4**, consistent with some embodiments.

FIG. **6** is a diagram illustrating another challenge that may be used to create a biometric model, consistent with some embodiments.

FIG. **7** is a diagram illustrating a user performing a challenge with optical biometric sensors.

FIG. **8** is a flowchart illustrating a process for authenticating a user using a biometric model, consistent with some embodiments.

FIG. **9** is a flowchart illustrating a process for creating a biometric model, consistent with some embodiments.

In the drawings, elements having the same designation have the same or similar functions.

DETAILED DESCRIPTION

In the following description specific details are set forth describing certain embodiments. It will be apparent, however, to one skilled in the art that the disclosed embodiments may be practiced without some or all of these specific details. The specific embodiments presented are meant to be illustrative, but not limiting. One skilled in the art may realize other material that, although not specifically described herein, is within the scope and spirit of this disclosure.

There is a need for a more secure biometric authentication system that constructs a biometric model associated with the user that is more unique to the user than current templates or models.

Consistent with some embodiments, there is provided a system for authenticating a user. The system includes one or more processors configured to determine a biometric model of the user, generate at least one challenge, determine an expected response based on the determined biometric model and the generated challenge, and determine if a received response matches the expected response within a predetermined degree of accuracy. The system also includes a biometric sensor configured to receive the response and a memory storing the determined biometric model. The system further includes a network interface component coupled to a network, the network interface component configured to transmit a successful authentication when the received response matches the expected response within a predetermined degree of accuracy.

Consistent with some embodiments, there is further provided a method for authenticating a user. The method includes steps of determining a biometric model of the user, storing the determined biometric model, generating at least one challenge in response to a request for authentication, determining an expected response based on the stored model and the generated at least one challenge, and transmitting a successful authentication when a received response matches the expected response within a predetermined degree of accuracy. The method may be embodied in non-transient computer-readable media.

These and other embodiments will be described in further detail below with respect to the following figures.

FIG. **1** is a block diagram of a networked system **100**, consistent with some embodiments. System **100** includes a client computing device **102** and a remote server **106** in communication over a network **108**. Remote server **106** may be a payment service provider server that may be maintained by a payment provider, such as PayPal, Inc. of San Jose, Calif. Server **106** may be maintained by other service providers in different embodiments. Remote server **106** may also be maintained by an entity with which sensitive credentials and information may be exchanged with client computing device **102**.

Remote server **106** may be more generally a web site, an online content manager, a service provider, such as a bank, or other entity who provides content to a user requiring user authentication or login.

Network **108**, in one embodiment, may be implemented as a single network or a combination of multiple networks. For example, in various embodiments, network **108** may include the Internet and/or one or more intranets, landline networks, wireless networks, and/or other appropriate types of communication networks. In another example, the network may comprise a wireless telecommunications network (e.g., cellular phone network) adapted to communicate with other communication networks, such as the Internet.

Client computing device **102**, in one embodiment, may be implemented using any appropriate combination of hardware and/or software configured for wired and/or wireless communication over network **108**. For example, client computing device **102** may be implemented as a wireless telephone (e.g., smart phone), tablet, personal digital assistant (PDA), notebook computer, personal computer, a connected set-top box (STB) such as provided by cable or satellite content providers, or a video game system console, a head-mounted display (HMD) or other wearable computing device, and/or various other generally known types of computing devices. Consistent with some embodiments, client computing device **102** may include any appropriate combination of hardware and/or software having one or more processors and capable of reading instructions stored on a tangible non-transitory machine-readable medium for execution by the one or more processors. Consistent with some embodiments, client computing device **102** includes a machine-readable medium, such as a memory (not shown) that includes instructions for execution by one or more processors (not shown) for causing client computing device **102** to perform specific tasks. For example, such instructions may include authentication app **112** for authenticating client computing device **102** to remote server **106**. Consistent with some embodiments, authentication app **112** may be a mobile authentication app, which may be used to authenticate user **120** to remote server **106** over network **108**. Authentication app **112** may include a software program, such as a graphical user interface (GUI), executable by one or more processors that is configured to interface and communicate with the remote server **106** or other servers managed by content providers or merchants via network **108**.

Client computing device **102** may also include biometric model application **114** for creating a biometric model and issuing biometric challenges based on the created model for authenticating a user of computing device **102** to remote server **106**. Client computing device **102** may also include sensor applications **116**. Consistent with some embodiments, sensor applications **116** include applications which utilize sensor capabilities within client computing device **102** to monitor characteristics of device **102**, user **120**, and/or the environment surrounding client computing device **102**. Such characteristics include obtaining images (video or still) of user **120** using camera functionalities of client computing device **102**, obtaining accelerometer readings using an accelerometer in client computing device **102**, using a geographical location of user **120** and/or client mobile device using global positioning system (GPS) functionality of client computing device **102** and/or obtaining a relative location using an internet protocol (IP) address of client computing device **102**. Consistent with some embodiments, characteristics of client computing device **102**, user **120**, and/or the environment around client computing device **102** may be captured using sensor applications **116** and used by authentication app **112** for authentication purposes. Further, sensor applications **116** may work with biometric model application **114** and authentication application **112** for capturing and creating a biometric model of user **120** for use in authentication with remote server **106**.

Client computing device **102** may also include other applications **118** as may be desired in one or more embodiments to provide additional features available to user **120**, including accessing a user account with remote server **106**. For example, applications **118** may include interfaces and communication protocols that allow the user to receive and transmit information through network **108** and to remote server **106** and other online sites. Applications **118** may also include security applications for implementing client-side security features, programmatic client applications for interfacing with appropriate application programming interfaces (APIs) over network **108** or various other types of generally known programs and/or applications. Applications **118** may include mobile apps downloaded and resident on client computing device **102** that enables user **120** to access content through the apps.

Remote server **106** according to some embodiments, may be maintained by an online payment provider, which may provide processing for online financial and information transactions on behalf of user **120**. Remote server **106** may include at least authentication application **122**, which may be adapted to interact with authentication app **112** of client computing device **102** over network **108** to authenticate client computing device **102** to remote server **106**. Remote server **106** may also include an application database **124** for storing various applications for interacting with client computing device **102** over network **108** for purposes other than authentication. Such applications may include applications for authentication, conducting financial transactions and shopping and purchasing items.

FIG. **2** is a diagram illustrating computing system **200**, which may correspond to any of client computing device **102** or remote server **106**, consistent with some embodiments. Computing system **200** may be a mobile device such as a smartphone, a tablet computer, a personal computer, laptop computer, netbook, or tablet computer, set-top box, video game console, head-mounted display (HMD) or other wearable computing device as would be consistent with client computing device **102**. Further, computing system **200** may also be a server or one server amongst a plurality of servers, as would be consistent with remote server **106**. As shown in FIG. **2**, computing system **200** includes a network interface component (NIC) **202** configured for communication with a network such as network **108** shown in FIG. **1**. Consistent with some embodiments, NIC **202** includes a wireless communication component, such as a wireless broadband component, a wireless satellite component, or various other types of wireless communication components including radio frequency (RF), microwave frequency (MWF), and/or infrared (IR) components configured for communication with network **108**. Consistent with other embodiments, NIC **202** may be configured to interface with a coaxial cable, a fiber optic cable, a digital subscriber line (DSL) modem, a public switched telephone network (PSTN) modem, an Ethernet device, and/or various other types of wired and/or wireless network communication devices adapted for communication with network **108**.

Consistent with some embodiments, computing system **200** includes a system bus **204** for interconnecting various components within computing system **200** and communication information between the various components. Such components include a processing component **206**, which may be one or more processors, micro-controllers, or digital signal

processors (DSP), or graphics processing units (GPUs), a system memory component **208**, which may correspond to random access memory (RAM), an internal memory component **210**, which may correspond to read-only memory (ROM), and an external or static memory **212**, which may correspond to optical, magnetic, or solid-state memories. Consistent with some embodiments, computing system **200** further includes a display component **214** for displaying information to a user **120** of computing system **200**. Display component **214** may be a liquid crystal display (LCD) screen, an organic light emitting diode (OLED) screen (including active matrix AMOLED screens), an LED screen, a plasma display, or a cathode ray tube (CRT) display. Computing system **200** may also include an input component **216**, allowing for a user **120** of computing system **200** to input information to computing system **200**. Such information could include payment information such as an amount required to complete a transaction, account information, authentication information, or identification information. An input component **216** may include, for example, a keyboard or key pad, whether physical or virtual. Computing system **200** may further include a navigation control component **218**, configured to allow a user to navigate along display component **214**. Consistent with some embodiments, navigation control component **218** may be a mouse, a trackball, or other such device. Moreover, if device **200** includes a touch screen, display component **214**, input component **216**, and navigation control **218** may be a single integrated component, such as a capacitive sensor-based touch screen.

Computing system **200** may perform specific operations by processing component **206** executing one or more sequences of instructions contained in system memory component **208**, internal memory component **210**, and/or external or static memory **212**. In other embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the present disclosure. Logic may be encoded in a computer readable medium, which may refer to any medium that participates in providing instructions to processing component **206** for execution. Such a medium may take many forms, including but not limited to, non-volatile media or volatile media. The medium may correspond to any of system memory **208**, internal memory **210** and/or external or static memory **212**. Consistent with some embodiments, the computer readable medium is tangible and non-transitory. In various implementations, non-volatile media include optical or magnetic disks, and volatile media includes dynamic memory. Some common forms of computer readable media include, for example, floppy disk, flexible disk, hard disk, magnetic tape, any other magnetic medium, CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer is adapted to read.

In various embodiments of the present disclosure, execution of instruction sequences to practice the present disclosure may be performed by computing system **200**. In various other embodiments of the present disclosure, a plurality of computing systems **200** coupled by a communication link **220** to network **108** (e.g., such as a LAN, WLAN, PTSN, and/or various other wired or wireless networks, including telecommunications, mobile, and cellular phone networks) may perform instruction sequences to practice the present disclosure in coordination with one another. Computing system **200** may transmit and receive messages, data and one or more data packets, information and instructions, including one or more programs (i.e., application code) through communication link **220** and network interface component **202**. Communication link **220** may be wireless through a wireless data protocol such as Wi-Fi™, 3G, 4G, HSDPA, LTE, RF, NFC, or through a wired connection. Network interface component **202** may include an antenna, either separate or integrated, to enable transmission and reception via communication link **220**. Received program code may be executed by processing component **206** as received and/or stored in memory **208**, **210**, or **212**.

Computing system **200** may also include sensor components **222** and biometric sensors **224**. Sensor components **222** and biometric sensors **224** may provide sensor functionality for sensor apps **116** and biometric model app **114**, and may correspond to sensors built into client computing device **102** or sensor peripherals coupled to client computing device **102**. Sensor components **222** may include any sensory device that captures information related to the surroundings of client computing device **102**. Sensor components **222** may include camera and imaging components, accelerometers, GPS devices, motion capture devices, and other devices that are capable of providing information about client computing device **102**, user **120**, or their surroundings. Biometric sensors **224** may include biometric readers, optical sensors such as camera devices, capacitive sensors such as may be found in a capacitive touch screen, pressure sensors, fingerprint readers, hand scanners, iris scanners, electromagnetic sensors that detect the EM field produced by a hand, and the like. Consistent with some embodiments, sensor components **222** and biometric sensors **224** may be configured to work with sensor applications **116** and biometric model application **114** to collect biometric information from user **120** that may be used to create a biometric model associated with user **120** that may be used for authenticating to remote server **106**.

FIG. **3** is a diagram illustrating a biometric model of a user's hand, consistent with some embodiments. As shown in FIG. **3**, model **300** includes unknowns that may be determined by requiring user **120** to perform challenges that are designed to determine the value of the unknowns and complete the model. Some of the values may be related by equations and, thus, some unknown values may be determined through the determination of other values. Model **300** may include such values as a distance from the finger joints on the hand to the finger tips, angles of the fingers on the hand, the maximum lengths of the fingers, the length of the thumb, and a basis line from which a thumb can move, some of which are shown in FIG. **3**. For example, the little finger has a length of d**1** and can move radially over an angle γ. The ring finger has a length of d**2**, and can move radially over an angle δ. The middle finger has a length of d**3** and can move radially over an angle ϵ. The index finger has a length of d**4** and can move radially over an angle ζ. The thumb has a length of d**5** and can move radially over an angle η. Moreover, there is an angle β between one side of the palm and the other side. Further, the thumb can move radially outward from the palm to create an angle α with a centerline C of the palm. These distances and angles, once determined, may be used to define a model of the hand that may uniquely identify user **120**. Consequently, once the model has sufficient data to ensure a reasonably probability that user **120** is who they are claiming to be, authentication app **112** may use the biometric model for authentication to remote server **106** based on the probability. The model shown in FIG. **3** is just one biometric model that may be used for authentication purposes. Different biometric models with different unknowns and degrees of security may be constructed and used for authentication, and such models are within the spirit and scope of this disclosure.

FIG. **4** is a diagram illustrating an example of a challenge that may be used to create a biometric model, consistent with some embodiments. As shown in FIG. **4**, a challenge may be displayed by a display component **214** of client computing device **102** that asks user **120** to align a biometric identifier with respect to biometric sensors **224**. As particularly shown in FIG. **4**, the challenge requires user **120** to align their fingertips with the indicated areas displayed on display component **214** by placing their fingers on the indicated areas of display component **214**. The challenge may include labeled circles indicating which finger to place in which circle, as shown in FIG. **4**. The challenge may also include displayed instructions, such as shown in FIG. **4**. According to some embodiments, other instructions may be displayed in order to provide user **120** with enough information to perform the displayed challenge. Information concerning the challenge may also be displayed to user. This information may include an indication when biometric sensor **224** has detected that user **120** has aligned a biometric identifier as required by the challenge. This information may also be provided by a displayed alert or an audible alert providing information to user **120**, or a displayed timer informing user **120** of how much time user has to complete the alignment. The displayed challenge may be generated by processing component **206** executing instructions associated with biometric model application **114**. The generated challenge may be adaptive to attempt to obtain information that is not known about user **120**. In particular, the generated challenge may be a challenge designed to reduce an error with which biometric application **114** is able to identify user **120** within a predetermined probability. The challenge may be part of a training session designed to capture sufficient information to create a model, such as model **300**, or as part of a game that is designed to capture the same information. Consistent with some embodiments, the challenges are constrained challenges, meaning that there is a predetermined constraints associated with a response. Moreover, the challenges may be designed to model a three dimensional object, such as a hand, in two dimensions.

FIG. **5** is a diagram illustrating user performing the challenge shown in FIG. **4**, consistent with some embodiments. As shown in FIG. **5**, user **120** has placed their fingertips in the areas indicated by the challenge shown in FIG. **4**. Consistent with some embodiments, display component **214** is a touch screen device having sensors for detecting a touch of user and, thus, biometric sensors **224** and/or other sensors **222** are integrated into display component **214** and may be part of or a particular function associated with display component **214** and may be configured to detect a touch of user's **120** hand. Based on the detected locations, some of the unknowns shown in FIG. **3** may be determined to create the biometric model of user's **120** hand. Performing the challenge, such as shown in FIG. **5**, may produce a response that has some truth and error associated therewith. Processing component **206** may use normal statistical methods for fitting the response to the model such as model **300** to provide a model that has a maximum probability of corresponding to user **120**, with a minimum associated error.

FIG. **6** is a diagram illustrating another challenge that may be used to create a biometric model, consistent with some embodiments. As shown in FIG. **6**, the challenge requests that user **120** place their fingertips in similar locations to those shown in FIG. **4**. The challenge also requests that user **120** move radially towards their palm. This movement may be detected by biometric sensors **224** and/or other sensors **222** and used to determine additional information about model **300** such as the unknowns of α and η. Consistent with some embodiments, display component **214** is a touch screen device having sensors for detecting a touch of user and, thus, biometric sensors **224** and/or other sensors **222** are integrated into display component **214** and may be part of or a particular function associated with display component **214**.

The generated challenge may also be used to authenticate user **120**. Once computing device **102** has sufficient information to reasonably identify user **120** beyond a predetermined probability, computing device **102** may generate challenges that fit the created model and should be uniquely identified with user **120**. Consequently, performing the challenge shown in FIG. **6** may authenticate user **120** to remote server **106**.

FIG. **7** is a diagram illustrating a user performing a challenge with optical biometric sensors. As described previously biometric sensors **224** and other sensors **222** may include optical sensors such as a camera that may be configured for sensing a position and depth of field of user **120** for creating a two-dimensional model **300** from a three-dimensional object. The camera may be coupled to a set-top box, a personal or laptop computer, or a wearable computing device having a head-mounted display such as an eyeglass projection sensor. As shown in FIG. **7**, computing device **102** may generate a similar challenge to the challenge that was generated on the touch screen device shown in FIGS. **4-6**, but adapted for an optical or other biometric sensor shown in FIG. **7**. In particular display component **214** may display the generated challenge along with instructions that allow biometric sensors **224** in combination with other sensors **222** to obtain sufficient information about user **120** to create a biometric model, such as model **300**, and then authenticate user using the created model. The instructions may include text, a displayed motion demonstrating the challenge, or a voice command, providing instructions for aligning a biometric identifier to complete the challenge, and may also include an indication when the alignment is complete and a timer indicating how long user **120** has left to complete the challenge.

FIG. **8** is a flowchart illustrating a process **800** for authenticating a user using a biometric model, consistent with some embodiments. For the purpose of illustration, FIG. **8** will be described with reference to any of FIGS. **1-7**. Process **800** shown in FIG. **8** may be embodied in computer-readable instructions for execution by one or more processors in processing component **206** such that the steps of process **800** may be performed by client computing device **102**. As shown in FIG. **8**, process **800** begins by determining a biometric model (**802**), Consistent with some embodiments, determining a biometric model may include issuing at least one challenge and receiving responses to the challenges. The at least one issued challenge may be part of a training set up that may be performed during an initial set up of client computing device **102**. The responses may be issued in order to learn unknown values of the model. For example, to determine model **300**, challenges may be issued in order to learn distances d**1**-d**5** and radial values α, β, δ, γ, ϵ, ζ, and η, which may be an angle or a radial distance. Moreover, the issued challenges may be adaptive such that a successive challenge attempts to determine values that a previous response did not provide. Further, the challenges may determine which values have the greatest source of error and issue challenges in order to attempt to reduce this error. A method for determining a biometric model is described in additional detail below with reference to FIG. **9**.

After a model has been determined, the model is stored (**802**). Consistent with some embodiments, the model may be stored locally in client computing device **102** in any of memories **208**, **210**, and **212**. In some embodiments, the model may

be stored on remote server **106**, which may a service provider server or an identity clearinghouse server. While the model may be stored, it may be modified over time to change and adapt with user **120** as they change or age by issuing additional challenges to retrain and re-determine the model. Computing device **102** may then request authentication to remote server **106** (**806**). According to some embodiments, the request for authentication is issued to remote server in response to user **120** attempting to access features provided by remote server **106** using computing device **102**. In response to the request for authentication, authentication app **122** on remote server may send a message that triggers authentication app **112** of computing device to generate at least one challenge (**808**). According to some embodiments, the at least one challenge may be generated based on the stored biometric model.

After the challenge is generated, processing component **206** of computing device may calculate an expected response based on the stored biometric model and the generated challenge (**810**). Computing device **102** may then receive a response to the generated challenge (**812**). Consistent with some embodiments, the response may be received by biometric sensors **224** or other sensors **222**, or a combination thereof. Further, the response may be received by display component **214** which may be a touch screen device that incorporates biometric sensors **224**. The response may also be received by biometric sensors **224** that are separate from but coupled to computing device **102**. Processing component may then determine if the received response fit the calculated expected response within a predetermined degree of accuracy (**814**). According to some embodiments, if the response does not fit the expected response within a predetermined degree of accuracy, computing device **102** may generate a subsequent challenge based on the stored model (**808**). However, if the response fits the expected response within a predetermined degree of accuracy, computing device **102** may transmit an indication to remote server **106** that the authentication was successful (**816**). According to some embodiments, the transmitted indication may be in the form of a token, certificate, or other secure identifier of a successful authentication.

According to some embodiments, the predetermined degree of accuracy achieved by the response may determine the level of access user **120** has to services offered by remote server **106**. For example, a very high degree of accuracy achieved (i.e., very small error), indicates a very high probability that user **120** is who they are claiming to be, and more services, or a higher tier of services, may be provided to user **120**. Similarly, a low, but passing, degree of accuracy indicating higher error, may indicate a good probability that user **120** is who they are claiming to be and may allow a lower tier of services. A geographical location of user **120** may also be captured and used to determine a user's **120** access to services based on a known or past location of user **120**. Tiered authentication is further described in U.S. application Ser. No. 13/605,886, filed on Sep. 6, 2012, the entire contents of which are hereby incorporated by reference in their entirety.

FIG. **9** is a flowchart illustrating a process **900** for creating a biometric model, consistent with some embodiments. For the purpose of illustration, FIG. **9** will be described with reference to any of FIGS. **1-7**. Process **900** shown in FIG. **9** may be embodied in computer-readable instructions for execution by one or more processors in processing component **206** such that the steps of process **900** may be performed by client computing device **102**. As shown in FIG. **9**, process **900** begins by generating a challenge (**902**). According to some embodiments, the challenge may be generated by biometric model application **114**, and may be a challenge designed to obtain a model that is tailored to computing device **102** and user **120**. For example, if computing device **102** has biometric sensors **224** that are limited in size, the biometric model that may be created may be a more limited model or uses different measurements to obtain the model and, as a result, issues appropriate challenges. Moreover, if computing device **102** uses optical sensors for obtaining biometric readings, such as shown in FIG. **7**, the generated challenge may be tailored for optical 2D modeling of a 3D object such as a hand of user **120**.

Computing device **102** may then receive a response to the generated challenge (**904**). Consistent with some embodiments, the response may be received by biometric sensors **224** or other sensors **222**, or a combination thereof. Further, the response may be received by display component **214** which may be a touch screen device that incorporates biometric sensors **224**. The response may also be received by biometric sensors **224** that are separate from but coupled to computing device **102**. Processing component **206** may fit the received response to the model (**906**). Processing component **206** may then determine if the model is sufficiently accurate (**908**), wherein sufficiently accurate refers to having a model that can identify user within a predetermined degree of accuracy. If the model is sufficiently accurate such that user **120** can be identified using the model with a predetermined degree of accuracy, the model will be stored (**910**). Consistent with some embodiments, the model may be stored locally in client computing device **102** in any of memories **208**, **210**, and **212**. In some embodiments, the model may be stored on remote server **106**, which may a service provider server or an identity clearinghouse server. While the model may be stored, it may be modified over time to change and adapt with user **120** as they change or age by issuing additional challenges to retrain and re-determine the model.

If the model is not sufficiently accurate, processing component **206** may determine a point of substantial error in the model (**912**). Consistent with some embodiments, a point of substantial error may be a missing distance or angle, or other value in which insufficient information has been obtained. That is, a point of substantial error may be a missing value or value having insufficient information such that a user **120** cannot be identified using a model within a predetermined degree of accuracy. Once a point of substantial error has been determined, a challenge that attempts to address the determined substantial point of error is generated (**914**). Consequently, biometric model application **114** executed by one or more processors of processing component **206** may repeat steps **904**, **906**, **908**, **912**, and **914** until the model is determined to be sufficiently accurate, and then stored. That is, the generated challenges may be adaptive so that they attempt to address substantial points of error in the model to improve the model until it is sufficient so that user **120** can be identified using the model within a predetermined degree of accuracy.

Software, in accordance with the present disclosure, such as program code and/or data, may be stored on one or more machine-readable mediums, including non-transitory machine-readable medium. It is also contemplated that software identified herein may be implemented using one or more general purpose or specific purpose computers and/or computer systems, networked and/or otherwise. Where applicable, the ordering of various steps described herein may be changed, combined into composite steps, and/or separated into sub-steps to provide features described herein.

Consequently, embodiments as described herein may provide systems and methods for authentication based on a biometric model of a user. In particular, embodiments as described herein determine a biometric model of a user and

then generate challenges based on the biometric model. The response to the challenges may be fit to the model, an error associated with the fitted response may be determined, and a user may be authenticated if the error is within a predetermined range. Moreover, the user may be granted tiered authentication based on the error, wherein lower error provides greater privileges, and higher error provides lesser privileges. The examples provided above are exemplary only and are not intended to be limiting. One skilled in the art may readily devise other systems consistent with the disclosed embodiments which are intended to be within the scope of this disclosure. As such, the application is limited only by the following claims.

What is claimed is:

1. A system for authenticating a user, comprising:

one or more processors configured to:

determine a biometric model of the user including at least a distance from a joint of a finger of the user, a length of a finger of the user, or a range of motion of a finger of the user;

generate at least one challenge;

determine an expected response based on the determined biometric model and the generated challenge; and

determine if a received response matches the expected response within a predetermined degree of accuracy;

a biometric sensor configured to receive the response;

a memory, the memory storing the determined biometric model; and

a network interface component coupled to a network, the network interface component configured to transmit a successful authentication when the received response matches the expected response within a predetermined degree of accuracy.

2. The system of claim **1**, wherein the one or more processors, to determine a biometric model of the user, are further configured to:

generate a first challenge;

receive a first response to the first challenge;

fit the first response to a model;

determine a point of substantial error in the model; and

generate an additional challenge to address the point of substantial error.

3. The system of claim **2**, wherein the one or more processors are further configured to generated additional challenges to address the points of substantial error until the model is sufficiently accurate to identify the user within a predetermined probability.

4. The system of claim **2**, wherein the response to the first challenge includes values that may be fit to unknown values in the model.

5. The system of claim **1**, wherein the biometric sensor comprises at least one of a touch sensor, a pressure sensor, an electromagnetic sensor, and optical sensor, and a combination thereof.

6. The system of claim **1**, wherein the at least one challenge is generated based on the determined biometric model.

7. The system of claim **1**, wherein the at least one challenge requires the user to position a biometric identifier in alignment with a graphical instruction, and further comprising:

a display component configured to display the graphical instruction; and

an indicator configured to provide an indication of when the alignment is complete.

8. The system of claim **7**, wherein the display component comprises at least one of a touch screen device, a display of a wearable computing device, an eyeglass projection screen, and a touch sensor.

9. The system of claim **7**, wherein the graphical instruction comprises at least one of a displayed hand motion and a timer indicating how long the user has left to respond to the challenge and the indication comprises at least one of a displayed hand motion and a generated audible command.

10. A non-transitory computer-readable medium having instructions for execution by one or more processors that, when executed, cause the one or more processors to perform a method for authenticating a user, the method comprising:

determining a biometric model of the user including at least a distance from a joint of a finger of the user, a length of a finger of the user, or a range of motion of a finger of the use;

storing the determined biometric model;

generating at least one challenge in response to a request for authentication;

determining an expected response based on the stored model and the generated at least one challenge; and

transmitting a successful authentication when a received response matches the expected response within a predetermined degree of accuracy.

11. The computer-readable medium of claim **10**, wherein determining a biometric model of the user comprises:

generating a first challenge;

receiving a first response to the first challenge;

fitting the first response to a model;

determining a point of substantial error in the model; and

generating an additional challenge to address the point of substantial error.

12. The computer-readable medium of claim **11**, further comprising generating additional challenges to address the points of substantial error until the model is sufficiently accurate to identify the user within a predetermined probability.

13. The computer-readable medium of claim **11**, wherein fitting the response to the model comprises determining values from the response and fitting the determined values to unknown values in the model.

14. The computer-readable medium of claim **10**, wherein generating at least one challenge comprises generating at least one biometric challenge to be presented to the user on a biometric sensor.

15. The computer-readable medium of claim **14**, wherein generating at least one biometric challenge comprises generating at least one of a touch challenge, a pressure challenge, an optical challenge, an electromagnetic challenge, and a combination thereof.

16. The computer-readable medium of claim **10**, wherein generating the at least one challenge comprises generating the at least one challenge based on the determined biometric model.

17. The computer-readable medium of claim **10**, wherein generating the at least one challenge comprises:

requiring the user to position a biometric identifier in a particular alignment;

providing a graphical instruction of the particular alignment; and

indicating when the alignment is complete.

18. The computer-readable medium of claim **17**, wherein:

providing the graphical instruction comprises at least one of a displaying a hand motion and a timer indicating how long the user has left to respond to the challenge; and

indicating when the alignment is complete comprises at least one of displaying a hand motion and a generating audible command.

19. A system for authenticating a user, comprising:

one or more processors configured to:

determine a biometric model of the user;

generate at least one challenge, the at least one challenge requires the user to position a biometric identifier in alignment with a graphical instruction that comprises at least one of a displayed hand motion and a timer indicating how long the user has left to respond to the challenge;

determine an expected response based on the determined biometric model and the generated challenge; and

determine if a received response matches the expected response within a predetermined degree of accuracy;

a biometric sensor configured to receive the response;

a display component configured to display the graphical instruction;

an indicator configured to provide an indication of when the alignment is complete that comprises at least one of the displayed hand motion and a generated audible command;

a memory, the memory storing the determined biometric model; and

a network interface component coupled to a network, the network interface component configured to transmit a successful authentication when the received response matches the expected response within a predetermined degree of accuracy.

* * * * *